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Soil Chemical Properties of Raised Planting Beds in a Northern Idaho Forest

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RESEARCH

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RESEARCH SUMMARY

Forest soil productivity can deteriorate after harvest and site preparation as a result of changes in the physical, chemical, and biological environments. Nutrient depletion, especially nitrogen, is a major concern. The purpose of this study was to evaluate the planting bed (mound) as a means of enhancing early seedling survival and growth. Surface organic matter and mineral soil were mounded mechanically to form raised planting beds on two widely different habitat types. Soil nutrient concentrations of planting beds were compared to both scalped and undisturbed treatments on both sites. Total N, total P, pH, exchangeable Ca, Mg, and K were measured at the beginning of the growing season. Mineralizable N, ammonium, and nitrate were measured four times during the growing season. Seedling growth and nutrient content were evaluated at the end of the first growing season.

Total N, total P, and exchangeable cation concentrations were generally improved by mounding, although not always significantly ($P \leq 0.05$). A similar trend was true for available nitrogen concentrations. Nitrogen fluctuated throughout the growing season, but the scalped treatment had lower concentrations than either mounded or undisturbed soils. Soil nutrient concentrations were directly correlated with organic matter content of the treated soil. Organic residues also acted as a mulch to retain soil moisture and improve aeration.

First-year seedling response to the treatments was minimal because of nutrient carryover from the greenhouse production environment. At both sites, however, seedling total N was greater in the mounded and undisturbed treatment than in the scalped treatment. High N concentrations will likely benefit both short- and long-term seedling performance and overall site productivity.

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INTRODUCTION

Future productivity of forested sites in the Inland Northwest may be reduced through more intensive harvesting and increased mechanization. Productivity of forest stands is largely dependent on favorable soil physical, chemical, and biological properties. But forest operations like harvesting entail a high risk to all of these soil properties (Reisinger and others 1988). In many stands where whole tree harvesting is commonplace, nutrient depletion is a concern (Johnson 1983; Weetman and Webber 1972). Direct loss of nutrients from harvesting and site preparation occurs after removal of stems, branches, and twigs. In addition, nutrient losses through increased leaching to groundwater sources and erosion are major concerns to site recovery after harvesting (McColl and Grigal 1979).

It is common to use some type of site preparation after harvest to ensure adequate mineral soil exposure, seed germination, and early survival, or to reduce nonconifer, competitive vegetation (Morris and Lowery 1988). In the Western States, mechanical methods (scalping) or burning are used to prepare sites for both natural and artificial regeneration. Most often, these methods are used together, primarily to remove competing sprout vegetation (Stewart 1974). In contrast, forest management in the Gulf States has relied on site preparation by chopping, disking, and bedding for successful plantation establishment (McMinn 1969; Wilhite and Harrington 1965; Worst 1964). From a soils point of view, the aim of all these site preparation techniques is to ameliorate the physical properties of cutover sites by increasing the pore space (Shoulders and Terry 1978), by improving aeration and moisture availability (Hite 1976; Pritchett 1979), or by decreasing soil resistance to root penetration (Fox 1977; McKee and Shoulders 1974).

One benefit of forming the soil into planting beds is the concentration of nutrients at the planting microsite. Gutzwiler (1976) noted that the highest concentrations of nitrogen (N) and phosphorus (P) were found in the top mineral layer and organic matter of the forest floor. Organic matter concentrations are as much as one-third to one-half higher in mounded soil than in scalps (Pritchett and Wells 1978; Shultz and Wilhite 1974). Organic matter mixed with soil and mounded by bedding equipment decomposed quickly and released substantial quantities of nutrients. The accelerated decomposition of organic matter in mounds was also cited by Pritchett and Wells (1978) as a provider of nutrients for seedling growth and early establishment. Haines and Pritchett (1965) attributed increased growth of southern pine seedlings after bedding to this nutrient release. Mounding significantly increases calcium (Ca), magnesium (Mg), and potassium (K) (Shultz and Wilhite 1974), and also N and P concentrations (Attiwill and others 1985) at various depths in treated soil profiles.

Most work with soil mounding has been done on wet lowland sites. But in a few cases (Francis 1979; Frederick and others 1983; Gilmore and others 1968), mounding has been successful in improving tree growth and vigor on upland sites. Mounding also can ameliorate undesirable soil physical properties and can increase moisture and nutrient availability. The forming of beds by mounding surface organic matter and mineral soil has been shown to improve both physical properties and moisture retention of several soils in northern Idaho (Page-Dumroese and others 1986). This study compares the changes in important soil chemical properties brought about by mounding or scalping of two cutover sites in northern Idaho, and subsequent effects on first-year outplanted seedlings.

STUDY DESCRIPTION

The objective of this study was to compare raised planting beds with conventional site preparation treatments, both in terms of soil chemical properties, including total N, total P, pH, exchangeable cations (Ca, Mg, K), ammonium and nitrate levels, nitrogen mineralization potential, and first-year seedling growth response. This study was conducted on two productive habitat types with distinctively different regeneration problems. These two sites, located at differing elevations, provided a range of environmental conditions for evaluating the effectiveness of bedding as a means of ameliorating soil disturbance-related hazards to seedling survival, and performance in forest soils of the Inland Northwest.

SITE DESCRIPTION

Two sites, located on the Priest River Experimental Forest near Priest River, ID, were used in this study. The Experimental Forest lies on the westward slope of a spur of the Selkirk Mountains in northwestern Idaho.

One site is located at an elevation of 715 m above sea level on a flat bench adjoining the Priest River. It is the warmer and drier of the two sites, has the longer growing season, and is considered the harsher of the two sites. Burned in 1922, this site had been used as an area for studying flammability of forest fuels and was occupied by grasses, forbs, and a few lodgepole pine (*Pinus contorta* Dougl. ex Loud.). The soil is a coarse, loamy, mixed frigid Typic Xerochrept. The habitat type is classified as *Abies grandis / Symphoricarpos albus* (Cooper and others 1987). Annual precipitation averages 83.8 cm, with a mean annual temperature of 6.6 °C (Wellner 1976).

The second site is at an elevation of 1,456 m above sea level near Observatory Point in the Canyon Creek watershed. Slopes range from 10 to 35 percent and have north-to-northeast aspects. The soil is classified as a coarse, loamy, Typic Cryorthent; the habitat type is *Tsuga heterophylla / Clintonia uniflora* (Cooper and others 1987). This study area consisted of a mixed stand of western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.), and western white pine (*Pinus monticola* Dougl. ex D. Don). This is a highly productive forest site with stand volume increases of 8 m^3/ha/yr. It was clearcut and the slash piled and burned in the fall of 1981. Annual precipitation at this elevation averages 92.3 cm, and the mean annual temperature is 5.3 °C (Wellner 1976).

STUDY DESIGN

Both sites were mechanically prepared in the summer of 1982, and a randomized complete block experiment established at each site. At the low-elevation site, there were four treatments with four replications in one large block. The high-elevation site consisted of four treatments with three replications. It was divided into three separate 1-ha cutting areas having approximately the same slope, aspect, soil, and habitat type.

The treatments on these sites consisted of: (1) mounded soil beds with competing vegetation not removed, (2) mounded soil beds with competing vegetation removed manually in June and July, (3) a scalped area wherein the top 10 cm of organic matter and mineral topsoil were removed, and (4) an area essentially undisturbed after harvesting. Each treatment was approximately 30 m long and, for the mounded treatments, approximately 46 cm high. In May, the treatments were planted with locally adapted, container-grown Douglas-fir on a 1- by 1-m spacing.

Soil Sampling and Analysis

Soil samples were taken from each treatment four times during the growing season. Samples were collected from 15 randomly selected sites in each treatment replication, to a depth of ca. 30 cm; the approximate maximum depth of seedling roots at the end of the first growing season. All soil samples were passed through a 2-mm sieve and dried before analysis. Organic matter was determined by weight loss after combustion at 375 °C for 16 hours (Ball 1964). Soil total N and total P were analyzed by the Kjeldahl digestion method using the salicylic acid-sodium thiosulfate modification (Bremner and Mulvaney 1982) and assayed on a Technicon Auto Analyzer II. Soil exchangeable Ca, Mg, and K were extracted using 1*N* NH_4OAc and analyzed by atomic absorption techniques (Page 1982). Nitrogen mineralization was estimated using the anaerobic incubation technique (Powers 1980). Nitrate and ammonium contents were determined on 1*N* KCl extract using a Technicon Auto Analyzer II. Soil acidity was determined on a 2:1 water:soil mixture. Soil nutrient concentrations were corrected to reflect average rooting depths of seedlings in each treatment.

Foliage Sampling and Analysis

Entire seedlings were excavated and dried at 60 °C for 24 hours. Total root and top weight and top height were measured. Stems and foliage were analyzed together. Total N and total P were analyzed by Kjeldahl digestion methods using the salicylic acid-sodium thiosulfate modification (Bremner and Mulvaney 1982) and assayed on a Technicon Auto Analyzer II. Foliage samples for Ca, Mg, and K were dry ashed, extracted with 2*N* HNO_3, and assayed by atomic absorption techniques (Thomas 1982).

An analysis of variance was conducted on the data using a randomized complete block design. Treatment means were separated using Scheffe's multiple range test. All foliage and soil chemical analyses included sets of blanks, duplicates, and standard reference materials. Soil data from the two mounded treatments (with and without competing vegetation) were combined because (on each site) there were no significant differences in nutrient concentrations between them.

RESULTS AND DISCUSSION

Soil Properties

Mounded treatments had significantly higher organic matter levels ($P \leq 0.05$) than scalped treatments (table 1), but were not significantly different from the undisturbed treatment. Most of the forest floor remained intact on the undisturbed treatment, while the scalp treatment removed a significant portion of organic matter from the soil surface.

Table 1—Soil organic matter content (percent) and rooting zone depth (cm) as affected by site treatment. Different letters indicate significant differences ($P \leq 0.05$) among treatments

Treatment	Low elevation		High elevation	
	O.M.	Root depth	O.M.	Root depth
	Percent	*cm*	*Percent*	*cm*
Mounded	15.0a	24.5a	27.5a	23.8a
Scalped	9.4b	20.8b	14.5b	19.7c
Undisturbed	14.4a	20.9b	29.2a	20.6b

Table 2—Average year-end total and available nitrogen concentration, total phosphorus content, and pH as affected by site treatment. Different letters indicate significant differences ($P \leq 0.05$) between treatments

Treatment	Total N	Total P	NH_4	NO_3	Mineralized N	pH
	Percent		*mg/kg*			
Low elevation:						
Mounded	0.03a	0.27a	1.3a	1.3a	5.4a	5.7a
Scalped	.01a	.22a	.8ab	1.0a	.5a	6.1a
Undisturbed	.03a	.24a	.5b	.9b	1.7a	6.0a
High elevation:						
Mounded	.07a	.11a	10.1a	6.1a	47.7a	5.4a
Scalped	.03a	.07a	.5a	1.2b	3.8b	5.5a
Undisturbed	.03a	.12a	4.3a	4.9a	43.5a	5.4a

Soil acidity (pH) did not reflect site preparation treatment of the topsoil (table 2). But there were differences between sites, with the low-elevation site having a higher pH than the high-elevation site. This difference was likely caused by a combination of base cycling from the grasses present at the low site and the high decayed wood content of the soil at the high-elevation site.

Mounding consolidated woody materials and organic matter in the root zone and thereby raised soil nutrient levels. More total soil N was found at the high-elevation site than at the low site. Total N content increased as a result of the mounding process (table 2), although these differences were not significant among treatments due to high within-site variability. Scalping to remove topsoil and organic matter resulted in less total N. Losses up to 50 percent of N storage have been suggested by Morris and others (1983) in the southeastern United States. Available soil nitrogen levels were also higher in the mounded treatment (table 2).

The soil N mineralization potentials following each site treatment at four times during the growing season are shown in figures 1 and 2. At the low-elevation site in particular, potential N release from the soil was greatest after mounding. At both sites, scalping the soil had adverse effects on N mineralization. Other investigators have also shown that mechanical site preparation techniques that remove the topsoil reduce the N mineralization potential (Burger and Pritchett 1984; Fox and others 1986). Nitrate levels followed similar seasonal and treatment trends (figs. 3 and 4) and, as with nitrogen mineralization potential, the high-elevation site had higher N levels than the low-elevation site. This is probably a function of the relatively large quantity of organic matter at the high-elevation site. Ammonium concentrations (table 2) also followed these trends.

The mounded treatment slightly increased total P concentration through the mixing of organic matter. In contrast to N results, total P values were lowest at the high-elevation site (table 2). Since total P may be increased through addition of fresh vegetation (Alexander 1977), the higher values at the low elevation can be associated with the incorporation of grasses into the mounds.

Differences in exchangeable cations followed trends similar to the other nutrients at the low-elevation site (table 3). But this pattern was much weaker at the high-elevation site. Base concentrations were high in the scalped soil, although the differences among treatments were not significant. Similar results were reported by Shultz and Wilhite (1974). They also reported that mounding increased Ca, Mg, and K concentrations in the rooting zone.

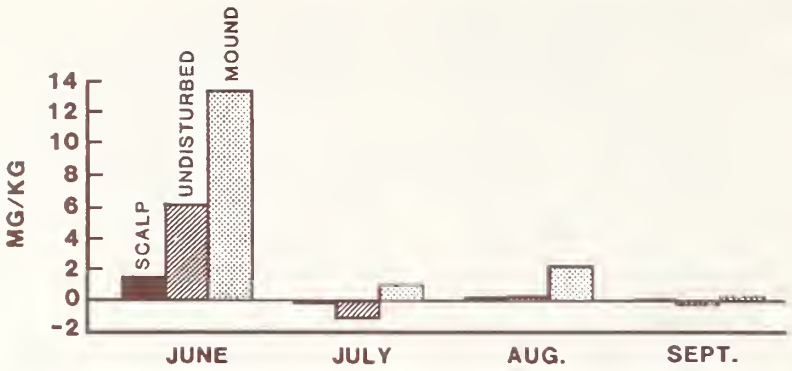

Figure 1—Treatment vs. mineralizable N potential for the low-elevation site.

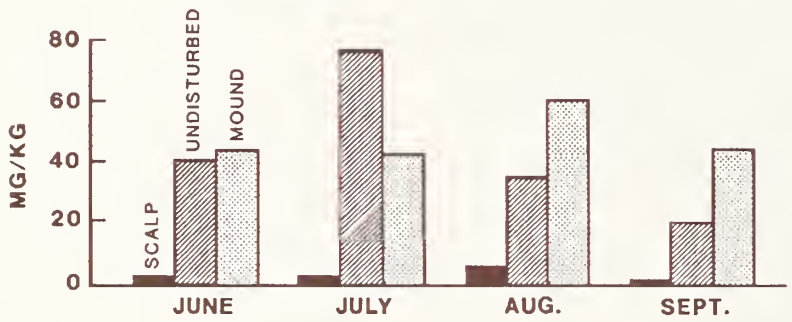

Figure 2—Treatment vs. mineralizable N potential for the high-elevation site.

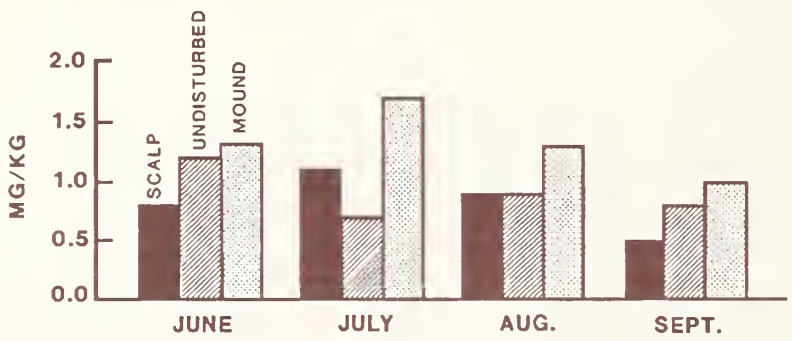

Figure 3—Treatment vs. nitrate levels for the low-elevation site.

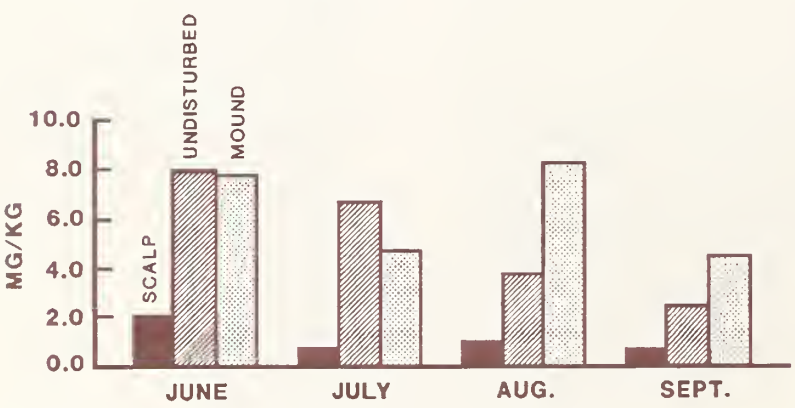

Figure 4—Treatment vs. nitrate levels for the high-elevation site.

Table 3—Average year-end cation concentration as affected by site treatment. Different letters indicate significant differences ($P \leq 0.05$) between treatments

Treatment	Low elevation			High elevation		
	Calcium	Magnesium	Potassium	Calcium	Magnesium	Potassium
	mg/kg			mg/kg		
Mounded	12.3a	3.7a	5.1a	10.5a	3.0a	4.7a
Scalped	4.4a	1.2b	2.4a	9.9a	2.5a	6.4a
Undisturbed	7.7a	1.9ab	3.3a	4.9b	2.6a	2.3a

Table 4—Average first-year physical and chemical properties of Douglas-fir seedlings as affected by site treatment. Different letters indicate significant differences ($P \leq 0.05$) between treatments

Treatment	Height	Root weight	Top weight	Total N	Total P	Ca	Mg	K
	cm	g		Percent		mg/kg		
Low elevation:								
Mounded	15.6a	8.2a	15.1a	0.13a	0.28a	467a	160a	946a
Scalped	15.0a	6.9ab	13.9a	.08b	.26a	479a	156a	890a
Undisturbed	15.5a	6.5b	14.3a	.11ab	.31a	512a	184a	1,062a
High elevation:								
Mounded	17.2a	7.3a	12.7a	.130a	.33a	469a	153a	941a
Scalped	15.2a	7.9a	10.9a	.072b	.29a	427a	160a	754a
Undisturbed	15.0a	6.8a	11.3a	.133a	.33a	422a	175a	929a

Seedling Properties

Rooting depth was significantly affected by mounding. At both elevations Douglas-fir seedlings in the mounded treatment had significantly greater rooting depth than those planted in undisturbed or scalped soil treatments. This may be due to the low bulk density and improved aeration (Page-Dumroese and others 1986). Seedlings grown at the low-elevation site in the undisturbed and the scalped treatment did not differ significantly from each other in rooting depth. At the high-elevation site, scalping significantly reduced rooting depth as compared to the undisturbed treatment. This is most likely associated with high bulk densities after scalping (Page-Dumroese and others 1986).

In general, seedling growth response to site treatment and nutrient uptake was not pronounced during the first growing season (table 4). Root weights were higher from the scalped treatment, but top weights were greater following soil mounding. At both sites total seedling N concentrations were higher for the mounded and undisturbed soil treatments. This likely reflects the increased availability of N in the mounded and undisturbed soils (table 2). Soil total P was greater at the low-elevation site, but seedling total P was slightly higher at the high-elevation site. This may reflect greater P mineralization rates at this elevation. First-year changes in other seedling nutrient uptake characteristics were not pronounced. This was not surprising, because outplanted seedlings usually have a store of nutrients in their buds and tissue from the nursery which greatly affects their first-year growth (Kozlowski and others 1973). But changes in soil properties adjacent to the root system may alter seedling uptake in subsequent years as roots begin growing outward.

CONCLUSIONS

Bedding had several favorable effects on the nutrient availability of two widely differing sites in northern Idaho. Organic matter levels were higher in the mounded treatment than the scalped treatment, which led to high microorganism activity and nutrient availability. Without adequate nutrient pools, long-term fertility problems can occur.

Total N, total P, Ca, Mg, K, and available N levels can be maintained by conserving organic matter after harvesting. Mounding increased nutrient concentrations in the root zone, but the undisturbed treatment also had substantial quantities of nutrients. The contrast between two sites used in this study illustrates that mounding, or at least an attempt to maintain organic matter, can create a very favorable environment for seedling growth.

After initial seedling establishment, the most important aspect of site preparation is the long-term growth effects. Removal of organic horizons severely limited N mineralization potential. Where initial N supplies are decreased, long-term N availability will also be reduced. This can lead to general declines in productivity. Conservation of organic matter is an important consideration when planning a harvest/site preparation sequence.

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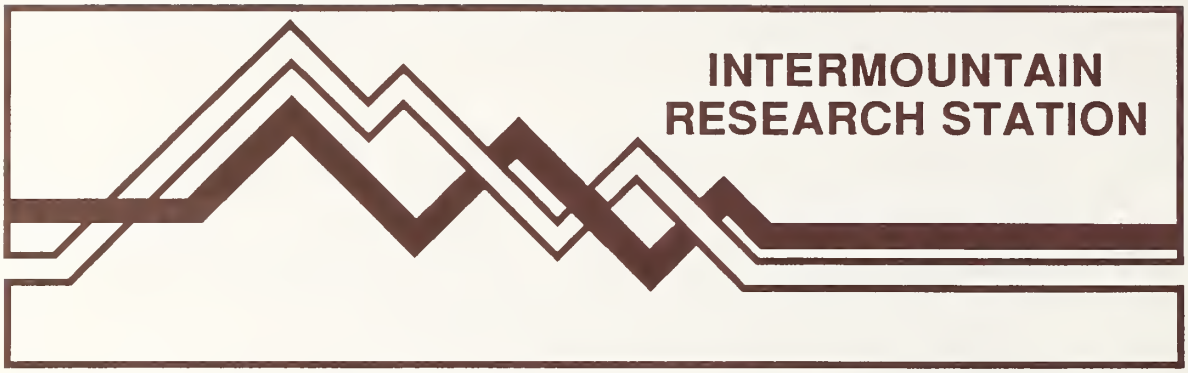
Mounded soil of mixed organic residues and mineral soil had higher concentrations of critical chemical components in seedling rooting zones when compared to scalped planting sites. Total N, total P, exchangeable Ca, Mg, and K, and available nitrogen were all improved by mounding. Improving chemical properties in planting beds (mounds) will likely enhance both survival and long-term growth of outplanted seedlings in many Inland Northwest soils. Although scalping increases early survival of conifer seedlings on sites with severe competition, reductions in both organic matter and nutrients, especially available nitrogen, may diminish site productivity over the long term.

KEYWORDS: site preparation, soil mounds, soil productivity, nutrient depletion



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The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

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